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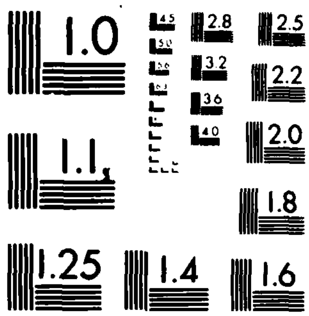

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INVESTIGATION OF MAGNETIC FIELD MEASUREMENTS

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28 February 1983

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AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This contract had as its basic requirement the maintenance of the Air Force Magnetometer Network and the additional task of upgrading and calibration of the instrumentation employed in the Network. To aid the calibration of instrumentation, the contract also required the recording of magnetic field components at Weston Observatory and the maintenance of a test facility. A firm program of upgrading was well underway when, in April 1981, the Sudbury station of the Network was destroyed by fire. The focus of the work then became the establishment of a Network Station on the grounds of Weston Observatory and the con- →

struction and purchase of equipment to replace that lost in the fire. During the last fifteen months of the contract the work effort concentrated on the construction of two data collection platforms. Support was also provided to AFGL to process the fluxgate magnetometer archive tapes in order to make the data available to the scientific community by deposition in WDC-A, Boulder, CO.

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1.1 Weston Geomagnetic Observatory

Under terms of the contract, Boston College was to maintain a test facility, three-component magnetic-field recordings along with a recording of a total-field magnetometer. The test facility had been constructed in 1963 under a prior contract. Over the years the facility has been used to test magnetometer packages, flown on rockets, and a wide variety of magnetic-field recording devices. In a limited volume, the coil system is capable of reproducing the magnetic field in space by cancelling the ambient magnetic field. An observatory-quality, proton-precession magnetometer is available to monitor the magnetic field changes during the test interval. The facility has been maintained so that it is ready for use on very short notice. It has been used primarily by groups from AFGL when preparing magnetometers for a variety of experiments.

The quality of the photographic recordings of the three magnetic components had deteriorated due to age of the equipment but primarily for lack of manpower to maintain and calibrate the instrumentation properly. Once the three-component fluxgate magnetometer came into operation at Weston, no effort had been made to maintain the photographic recordings. The Cesium total field magnetometer has been in operation continuously. During the winter of 1979-1980, extreme cold caused malfunction. More insulation of the sensor housing, adjustment of the internal heater current as well as a slight increase in operating voltage resulted in trouble-free operation. The output of the Cesium magnetometer is a frequency proportional to the existing field. This output is recorded on a strip chart at a speed of 2 inches/hour. The

frequency is converted by a microchip to a digital field value in gammas and is printed on a chart at ten-minute intervals. During severe magnetic disturbance, the gamma value is printed every minute.

For some years we had been calculating and plotting the value of the total field at midnight, magnetic time. Recently due to lack of manpower this has not been done. The digital recordings of the total field values have been used by various groups, (including the University of New Hampshire, Weston Geophysical Engineers, Boston College, the University of Rhode Island) to remove the daily variation from magnetic survey data. Weston Observatory provides the only total-field recording of the magnetic field in the Northeast.

2.1 Air Force Magnetometer Network

The construction of the Air Force Magnetometer Network, the instrumentation and early problems of maintenance have been detailed in prior reports. (1) The maintenance of the Network in operation was the principal task of the contract. Due to financial constraints, only one engineer was employed full time on maintenance and this required very close cooperation with AFGL personnel who were working on the project. In the early stages of the contract, failure at a station was reported to us by AFGL personnel who were monitoring the data as recorded at Hanscom AFB. Our engineer was sent to the site, very often accompanied by AFGL personnel. If it was possible to repair the failure on site, it was done, otherwise the equipment was replaced by spares and the failed equipment returned to Weston for repairs.

Dr. David Knecht of AFGL suggested the possibility of using government personnel at the Network stations to inspect on a regular

basis the stations and to make simple repairs or adjustments. Because the stations are on bases under different commands, the specific legal requirements at each site had to be met. Dr. Knecht drafted letters of agreement which had the approval of legal representatives of the Air Force and Boston College. Individuals at each site agreed to act as representatives of Boston College with the consent of their commanders. The availability of on-site assistance significantly reduced the need to travel for routine maintenance. Each site was furnished with detailed drawings of the equipment and a supply of components most likely to fail. Most often adjustments or replacements were made during telephoned contact with Weston Observatory. In some cases, equipment was shipped to the site, installed and the defective equipment sent to Weston. Because air fares, hotel rates and auto rental had increased significantly, the on-site personnel were an important factor in reducing costs of travel and increased station reliability. For example, the induction-coil magnetometer would cease to operate if the line voltage decreased momentarily below 105 volts. It would not restart when the voltage returned to normal. It required only that the operating switch be turned off and then on. On-site personnel were able to restore operation in a moment, rather than require travel by our personnel.

2.2 The Fluxgate Magnetometer

The fluxgate magnetometer, built by UCLA, has been considered the most important instrument in the AFGL Magnetometer Network. There were some problems, detailed in a prior report (1). Many of the difficulties were due to the original digital-to-analog converter (DAC). An improved DAC has been installed in each fluxgate, new fans and cermet

potentiometer installed, more ventilation holes drilled in the chassis and the original bubble levels replaced with far more sensitive ones. After these modifications, the instrument is now highly reliable.

But from the outset, the manufacturer found the magnetometer output to vary with temperature (2). Initially our tests of the temperature sensitivity were performed in the temperature-stabilized observatory building where fluxgate sensor and electronics were in the same stable environment as the standard Schonstedt fluxgate magnetometer. Tests of the Y-component at one baseline level showed an average positive drift of 1.7 ± 0.2 gammas per degree centigrade decrease of temperature of the electronics package. The outputs of the magnetometers were recorded on a strip chart. The temperature was recorded visually, a very time-consuming process. And there were indications that the temperature response was different for each component. Obviously the need was to record three components simultaneously along with the three components of the standard magnetometer and the temperature.

To automate the testing process, a small microcomputer was purchased. Cables were laid from the observatory building to the electronics laboratory so that instruments would not be disturbed by personnel. The computer was programmed to sample six channels of magnetometer data and the output from nine temperature sensors. A temperature controlled chamber, 2½X2½X2½ feet, mounted on casters and lined with three inches of foam insulation was constructed. There are two sections, each separately temperature controlled, one for the sensor, the other for the electronics. The temperature is controlled by small

heaters and measured by both the internal thermometer of the magnetometer and two additional sensors.

The testing program was just under way when the fire at Sudbury occurred and the spare fluxgate electronics was needed for the new station. In addition we had obtained for test from the TDK Corp. some PTC material, a semiconductor which, powered by A.C., tends to maintain a stable temperature, independent of input voltage and frequency. Properly selected and used with insulation, we judge it may help reduce or eliminate the temperature variation of the sensors. Since there is a pronounced drift of the sensors with temperature, they cannot be used as "absolute" instruments until the variation is fully documented.

2.3 The Induction Coil Magnetometer

The three component induction coil magnetometer, manufactured by Geotronics of Austin, TX, is the second set of instruments in the Air Force Magnetometer Network. From the outset its operation has been the source of many maintenance problems. The instrument was designed as a survey instrument for intermittent field work, not for continuous operation in an unattended observatory environment.

The most serious problem is its susceptibility to lightning-induced transients. Some attempts to protect the instrument from lightning are detailed in a prior report (1). These attempts have not been completely successful, though the number of failures has decreased. A plan had been developed to provide a new grounding system at the sites. The plan includes properly defined signal, shield and power grounds, installing the equipment on insulated surfaces, providing a common ground for the system including insulated van tie-downs and

elimination of connection between the external grounds of the power and telephone companies. This plan has not yet been activated because of the problems caused by the Sudbury fire.

The master oscillator was prone to failure. An inexpensive replacement was found and installed in all units when returned to Weston. The magnetometer at the Florida site was so severely damaged by lightning that it had to be returned to the manufacturer for repair.

Plans had also been made to design and build a replacement for the search-coil magnetometer. The state of the art in linear integrated circuits and modular assemblies has so developed that it may be possible to produce a low-cost replacement. The modular construction would maintain the best properties of the older units (low offset drift, low noise) and eliminate the problem causing properties (transient susceptibility). The modules could be easily replaced in a very short time. But to assure the reliability and continuous operation of any induction-coil magnetometer, additional means must be found to protect it from lightning.

2.4 A Three Component Magnetometer

The construction of a three-component magnetic observatory using a Cesium vapor total field magnetometer and a McKeehan three-axis coil had been the objective of a prior contract. To aid the testing and calibration of the fluxgate magnetometers, an effort was made to update the system and make the recording suitable for test purposes. We wanted to avoid scaling the photographic records of the magnetic field components (H,D,Z) whose accuracy depends on a scale factor of about 3 gammas/mm.

The vector components of the magnetic field are found by sequentially adding and subtracting magnetic fields caused by known currents along each axis. Mechanical wipers were used to switch the currents in the coils, but the contacts deteriorated with use and hence destroyed the accuracy of the component values calculated. This problem was eliminated by replacing the wipers with reed relays controlled by a microprocessor.

A MEK 6800 D2 microcomputer kit was purchased and the computer assembled. The microprocessor was programmed to switch the currents in the coils, to count the frequency output of the Cesium magnetometer and to calculate the component values in gammas. In addition the microprocessor also sensed the fluxgate component under test and fed all values to a paper-tape punch. The punched tape would be processed at the Boston College Computer Center. The system appeared to operate as planned, but there were inconsistencies in the field values. Close inspection of the coils revealed that at least one wire in the Z-axis coil was shorted to the aluminum coil frame and that the Y-axis coil has an intermittent internal short. Repair of the coil would be time consuming. Hence to continue the testing program, the AFGL Geomagnetism Branch loaned us the very high-quality three-component Schonstedt fluxgate mangetometer.

3.1 Effects of Fire at Sudbury Station

In early April 1981, the trailer at the Sudbury station of the AFGL Magnetometer Network was totally destroyed by fire. The trailer housed all the electronic components of the magnetometers and all equipment to transmit the data to Hanscom. It was decided to re-establish the station on the grounds of Weston Observatory. The

fluxgate sensors and the induction coil sensors with undamaged portions of the cables were brought to Weston. After securing additional but limited funds, the process of procuring components began. Orders were placed for an A/D converter and a Geotronics electronics package. A subcontract was awarded to UCLA for a fluxgate electronics package and two new sensors and their cables. Because of financial constraints AFGL decided to build, in-house, the data-collection platform (DCP). This proved to be a long and tedious job of wiring. A simulator of input data was required to test the DCP output to the telephone line and as an aid in troubleshooting the memory units of the DCP. The simulator was designed and built to provide a field of 32 digital words, each 11 bits wide, by switch selection.

Preparations were made at the Weston Observatory to house the fluxgate sensor in the existing magnetic observatory building and the A/D data-collection platform in a small control building. Because of long delivery time on the purchased equipment it was not until January 1982 that the fluxgate data were transmitted to Hanscom AFB. The shelters for the induction magnetometers were not constructed until Spring of 1982 when the frost was out of the ground. UCLA delivered the fluxgate magnetometers in December 1982.

The efforts to repair the damage, particularly the construction of the DCP, called for full-time efforts. But the maintenance of the other stations was also a task. In the summer of 1982, two stations, Florida and Newport, Washington were badly damaged by lightning. Repair of that equipment consumed many man hours. In October 1981, Edward A.

Johnson, who had worked on the project for seven years resigned. The loss of his familiarity with the instrumentation slowed the recovery phase.

3.2 Students

Some students have been employed at AFGL part-time under this contract. Initially they aided in the construction of the DCP's. Later, after they acquired familiarity with the data-acquisition system at Hanscom they have been able to support the effort to make the data available to the scientific community. The archive tapes are edited, the fluxgate-magnetometer data being extracted for one-second and one minute intervals, then reformatted, and written on magnetic tapes in the standard format required at AFGL and by the WDC-A, Boulder, Co.

4.1 Conclusion

The Air Force Magnetometer Network of seven geomagnetic observatories has operated with success for five years. Only the Florida station needs considerable refurbishment.

The fire at Sudbury station was a severe setback, diverting funds from development and testing to replacement of lost components. The entire operation will benefit from greatly enhanced computer facilities at Hanscom and the revived program to test and calibrate the fluxgate magnetometers. Changes in design of the induction-coil magnetometers should enhance their reliability. The value of the Network to the scientific community is increased by the availability of the data in the WDC-A.

PREVIOUS CONTRACTS

AF19 (604)3504	April 1, 1957	-	March 31, 1959
AF19 (604)5569	April 1, 1959	-	Sept. 30, 1961
AF19 (628) 236	Oct. 1, 1961	-	Oct. 31, 1964
AF19 (628)4793	Nov. 1, 1964	-	Oct. 31, 1967
F 19 (628)-68-C-0094	Nov. 1, 1967	-	Oct. 31, 1970
F 19 (628)-68-C-0100	Nov. 1, 1967	-	Oct. 31, 1970
F 19 (628)-71-C-0083	Nov. 1, 1970	-	July 31, 1973
F 19 (628)-74-C-0003	Aug. 1, 1973	-	June 30, 1976
F 19 (628)-76-C-0291	Jul. 1, 1976	-	Sept. 30, 1979

Contract Personnel

Supervisor

John F. Devane, S.J.

Engineer

Edward A. Johnson	October 1979 - October 1981
Albert Perkinson	December 1981 - September 1982

Clerical

Janet Reach	October 1979 - June 1980
Joy O'Malley	July 1980 - September 1983

Students

Bruce Whithey	March 1980 - June 1980
Armand Paboojian	July 1981
William Collyer	October 1981
Mark Kettering	October 1981
Glen A. Ellis	July 1981
Richard Laperriere	July 1981

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